The International Space Station and the Space Shuttle

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Summary

The International Space Station (ISS) program began in 1993, with Russia joining the United States, Europe, Japan, and Canada. Crews have occupied ISS on a 4-6 month rotating basis since November 2000.

The U.S. Space Shuttle, which first flew in April 1981, has been the major vehicle taking crews and cargo back and forth to ISS, but the shuttle system has encountered difficulties since the *Columbia* disaster in 2003. Russian Soyuz spacecraft are also used to take crews to and from ISS, and Russian Progress spacecraft deliver cargo, but cannot return anything to Earth, since they are not designed to survive reentry into the Earth's atmosphere. A Soyuz is always attached to the station as a lifeboat in case of an emergency.

President Bush, prompted in part by the *Columbia* tragedy, made a major space policy address on January 14, 2004, directing NASA to focus its activities on returning humans to the Moon and someday sending them to Mars. Included in this "Vision for Space Exploration" is a plan to retire the space shuttle in 2010. The President said the United States would fulfill its commitments to its space station partners, and the shuttle *Discovery* made the first post-*Columbia* flight to the ISS in July 2006. Shuttle flights have continued and completion of the space station is scheduled before the shuttle is retired in 2010. Meanwhile NASA has begun development of a new crew launch vehicle, named Ares, and a crew exploration vehicle, named Orion.

NASA programs were funded for FY2008 in Division B of the Consolidated Appropriations Act (P.L. 110-161). The Space Operations program, which includes the space shuttle and the ISS, was funded at $6.734 billion. For FY2009 NASA requested $5.775 billion for these programs, but in the process revised its budgeting to move its overhead costs to a new account called Cross-Agency Support. Under the new system, the FY2008 Space Operations program would have received $5.526 billion, about $250 million less than the FY2009 request. NASA is currently operating under a continuing resolution (Division A of P.L. 110-329), which funded most civilian activities through March 6, 2009. Under the continuing resolution, Space Operations are funded at the $5.526 billion rate appropriated for FY2008.

An FY2009 NASA authorization bill (H.R. 6063) was introduced May 15, 2008. Among the provisions in the one-year authorization bill was a "Sense of the Congress" urging cooperation in the Moon/Mars activities with other nations pursuing human space flight. It also requires that NASA "terminate or suspend any activity of the Agency that, if continued between the date of enactment of this Act and April 30, 2009, would preclude the continued safe and effective flight of the Space Shuttle after fiscal year 2010 if the President inaugurated on January 20, 2009, were to make a determination to delay the Space Shuttle's scheduled retirement." Congress passed the bill September 27, and it was signed by the President October 15 (P.L. 110-422).

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Most Recent Developments

With the signing of the Omnibus Appropriations Act for FY2009 (H.R. 1105, P.L. 111-5) on March 11, 2009, the National Aeronautics and Space Administration (NASA) was funded at $17.78 billion for the fiscal year. Of that total, $5.76 billion was allocated to Space Operations, which include the Space Shuttle and the International Space Station. For FY2008, NASA had received $5.53 billion for Space Operations.

As NASA continued to fly Space Shuttle missions to the International Space Station, the agency awaited the announcement of a new administrator to replace Michael Griffin, who resigned in January. On March 11 President Obama said he would appoint a new NASA director soon, and that one of biggest tasks of the new director would be "shaping a mission for NASA that is appropriate for the 21st Century."

The International Space Station (ISS)

NASA launched its first space station, Skylab, in 1973. Three crews were sent to live and work there in 1973-1974. It remained in orbit, unoccupied, until it reentered Earth's atmosphere in July 1979, disintegrating over Australia and the Indian Ocean. Skylab was never intended to be permanently occupied, but the goal of a permanently occupied space station with crews rotating on a regular basis, employing a reusable space transportation system (the space shuttle) was high on NASA's list for the post-Apollo years following the moon landings. Budget constraints forced NASA to choose to build the space shuttle first. The first launch of the shuttle was in April 1981. When NASA declared the shuttle "operational" in 1982, it was ready to initiate the space station program.

In his January 25, 1984 State of the Union address, President Reagan directed NASA to develop a permanently occupied space station within a decade, and to invite other countries to join. On July 20, 1989, the 20th anniversary of the first Apollo landing on the Moon, President George H. W. Bush voiced his support for the space station as the cornerstone of a long-range civilian space program eventually leading to bases on the Moon and Mars. That "Moon/Mars" program, the Space Exploration Initiative, was not greeted with enthusiasm in Congress, primarily due to budget concerns, and ended in FY1993, although the space station program continued.

President Clinton dramatically changed the character of the space station program in 1993 by adding Russia as a partner to this already international endeavor. That decision made the space station part of the U.S. foreign policy agenda to encourage Russia to abide by agreements to stop the proliferation of ballistic missile technology, and to support Russia economically and politically as it transitioned from the Soviet era. The Clinton Administration strongly supported the space station within certain budget limits.

The International Space Station program thus began in 1993, with Russia joining the United States, Europe, Japan, and Canada. An Intergovernmental Agreement (IGA) established three phases of space station cooperation. The IGA is a treaty in all the countries except the United States, where it is an Executive Agreement. It is implemented through Memoranda of Understanding (MOUs) between NASA and its counterpart agencies.

During Phase I (1995-1998), seven U.S. astronauts remained on Russia's space station *Mir* for long duration (several month) missions with Russian cosmonauts, Russian cosmonauts flew on the U.S. space shuttle seven times, and nine space shuttle missions docked with *Mir* to exchange crews and deliver supplies. Repeated system failures and two life-threatening emergencies on *Mir* in 1997 raised questions about whether NASA should leave more astronauts on *Mir*, but NASA decided *Mir* was sufficiently safe to continue the program. (*Mir* was deorbited in 2001.) Phases II and III involve construction of the International Space Station itself, and blend into each other. Phase II began in 1998 and was completed in July 2001; Phase III is underway.

President George W. Bush, prompted in part by the February 2003 space shuttle *Columbia* tragedy, made a major space policy address on January 14, 2004, directing NASA to focus its activities on returning humans to the Moon and eventually sending them to Mars. Included in this "Vision for Space Exploration" was a decision to retire the space shuttle in 2010. The President said the United States would fulfill its commitments to its space station partners.

ISS Design, Cost, Schedule, and Lifetime

Under the original ISS schedule, assembly of the station would have been completed in 2002, with operations at least through 2012. President Bush restructured the space station program in 2001, and left it unclear when assembly would be completed. NASA briefing charts in March 2003 showed space station operations possibly continuing until 2022. Under President Bush's January 2004 "Vision for Space Exploration," however, NASA plans to complete its utilization of ISS in 2016 (though the other partners may continue to use it after that time).

ISS segments have been and continue to be launched into space on U.S. or Russian launch vehicles and assembled in orbit. The space station is composed of a multitude of modules, solar arrays to generate electricity, remote manipulator systems, and other elements. (Details can be found at http://spaceflight.nasa.gov/home/index.html.)

The U.S. space shuttle has been the major vehicle taking crews and cargo back and forth to ISS, but the shuttle system encountered difficulties after the *Columbia* disaster and did not resume flights until 2006. Russian Soyuz spacecraft are also used to take crews to and from ISS, and Russian Progress spacecraft deliver cargo, but cannot return anything to Earth, since it is not designed to survive reentry into the Earth's atmosphere. A Soyuz is always attached to the station as a lifeboat in case of an emergency.

"Expedition" crews have occupied ISS on a 4-6 month rotating basis since November 2000. Originally the crews had three members (two Russians and one American, or two Americans and one Russian). Crew size was temporarily reduced to two (one American, one Russian) while the U.S. shuttle was grounded in order to reduce resupply requirements. The number of astronauts who can live on the space station is limited in part by how many can be returned to Earth in an emergency by lifeboats docked to the station. Only Russian Soyuz spacecraft are available as lifeboats. Each Soyuz can hold three people, limiting crew size to three if only one Soyuz is attached. The plan is that crew size will grow to six once assembly is completed.

Each Soyuz must be replaced every six months. The replacement missions are called "taxi" flights since the crews bring a new Soyuz up to ISS and bring the old one back to Earth. Therefore, under normal conditions, the long duration Expedition crews are regularly visited by taxi crews, and by the space shuttle bringing up additional ISS segments or exchanging

Expedition crews. When the shuttle is unavailable, Expedition crews are taken back and forth on the "taxi" flights.

In order to contract for Soyuz service to the ISS, NASA has needed an exemption from the Iran Nonproliferation Act (INA) (P.L. 106-178), which banned U.S. payments to Russia in connection with the International Space Station (ISS) unless the U.S. President determined that Russia was taking steps to halt proliferation of nuclear weapons and missile technology to Iran. In 2005 Congress amended INA to exempt Soyuz flights to the ISS from the ban through 2011. It also extended the provisions of the INA to Syria and North Korea, and renamed it the Iran, North Korea, and Syria Nonproliferation Act (INKSNA). NASA asked for a legislated extension of this exemption, and waiver authority was extended until July 1, 2016, in the Continuing Appropriations Act of 2009 (P.L. 110-329). (For details see CRS Report RL34477, *Extending NASA's Exemption from the Iran, North Korea, and Syria Nonproliferation Act*, by Carl E. Behrens and Mary Beth Nikitin.)

Space Station Costs

From FY1994 to FY2001, the cost estimate for building ISS grew from $17.4 billion to about $25 billion. The $17.4 billion estimate did not include launch costs, operational costs after completion of assembly, civil service costs, or other costs. NASA estimated the program's life-cycle cost (all costs, including funding spent prior to 1993) from FY1985 toFY2012 at $72.3 billion. In 1998, GAO estimated the life-cycle cost at $95.6 billion (GAO/NSIAD-98-147). More recent, comparable, life-cycle estimates are not available from NASA or GAO.

As costs continued to rise, Congress voted to legislate a $25 billion cap on development of the ISS program, plus $17.7 billion for associated shuttle launches, in the FY2000-FY2002 NASA authorization act (P.L. 106-391). In January 2001, however, NASA announced that the cost would be over $30 billion, 72% above the 1993 estimate, and $5 billion above the legislated cap. NASA explained that program managers had underestimated the complexity of building and operating the station. The Bush Administration signaled it supported the legislated cap, would not provide additional funds, and NASA would have to find what it needed from within its Human Space Flight account.

"Core Complete" Configuration

In February 2001, the Bush Administration announced it would cancel or defer some ISS hardware to stay within the cap and control space station costs. The decision truncated construction of the space station at a stage the Administration called "core complete." In 2001, the space station program office at Johnson Space Center (JSC) estimated that it would cost $8.3 billion from FY2002 toFY2006 to build the core complete configuration, described at that time as all the U.S. hardware planned for launch through "Node 2," plus the launch of laboratories being built by Europe and Japan. NASA subsequently began distinguishing between "U.S. Core Complete" (the launches through Node 2, which, prior to the *Columbia* tragedy, was scheduled for February 2004) and "International Partner (IP) Core Complete" which included the addition of European and Japanese laboratory modules (then anticipated in 2008).

The new policy was followed by President Bush's January 2004 "Vision for Space Exploration," which directs that U.S. research on ISS be restricted only to that which supports the Vision. A

new research plan, incorporating the President's Vision, was issued by NASA in June 2006, as mandated by the 2005 NASA authorization act (P.L. 109-155).[1]

At a January 2005 Heads of Agency meeting, the partners endorsed a final configuration of ISS, but NASA subsequently announced changes to it. The agency now plans to conduct only 16 (instead of 28) shuttle launches to the ISS, all before the end of FY2010 (September 30, 2010), and has dropped plans to launch the centrifuge and its accommodation module, and Russia's Science Power Platform. The agency plans to meet with the other ISS partners to discuss these changes.

The changes to the ISS are largely due to the new direction NASA is taking in response to the Vision for Space Exploration. The Vision calls for development of a Crew Exploration Vehicle, now named Orion, to take astronauts to and from the Moon, and a Crew Launch Vehicle, now named Ares I. Orion also can take them to and from the ISS, and NASA Administrator Griffin stated at a September 19, 2005 press conference that Orion would be used to take crews to and from the ISS, and to serve as a lifeboat for them. If Orion is built as announced, it would fulfill the U.S. commitment to build a crew return capability, and allow the ISS crew size to increase to its originally planned complement of seven. An Earth-orbit capability is planned by 2014 (although NASA now considers early 2015 more likely) with the ability to take astronauts to and from the Moon following no later than 2020.

Table 1. U.S. Space Station Funding

(in $ millions)

Fiscal Year	Request	Appropriated
1985	150	150
1986	230	205
1987	410	410
1988	767	425
1989	967	900
1990	2,050	1,750
1991	2,430	1,900
1992	2,029	2,029
1993	2,250	2,100
1994	2,106	2,106
1995	2,113	2,113
1996	2,115	2,144
1997	2,149	2,149
1998	2,121	2,441[a]

[1] The National Aeronautics and Space Administration (NASA).*Research and Utilization Plan for the International Space Station (ISS) A Report to the Committee on Science of the United States House of Representatives and the Committee on Commerce, Science, and Transportation of the United States Senate*. June 2006. http://www.exploration.nasa.gov/documents/reports/NASA_Research_and_Utilization_Plan_for_the_ISS.pdf

Fiscal Year	Request	Appropriated
1999	2,270	2,270
2000	2,483	2,323
2001	2,115	2,115
2002	2,114	2,093
2003	1,839	1,810
2004[b]	2,285	2,085
2005	2,412	2,058
2006	1,995	1,972
2007	1,894	NA[c]
2008	1,894	2,209
2009	2,060[d]	2,060

Note: These numbers reflect NASA's figures for "the space station program." Over the years, what is included in that definition has changed. In recent years, funding for ISS research has been located in a different account from ISS development funding. The figures here represent the ISS development and ISS research request and appropriations to the maximum extent possible.

a. NASA's FY1999 budget documents showed $2.501 billion in the expectation Congress would approve additional transfer requests, but it did not.

b. Reflects shift to full cost accounting.

c. Space shuttle funding was not specified in P.L. 110-5.

d. Reflects change in budgeting for overhead costs.

The Space Shuttle

The Space Transportation System (STS)—the Space Shuttle—is a partially reusable launch vehicle and is the sole U.S. means for launching humans into orbit. It consists of an airplane-like Orbiter, with two Solid Rocket Boosters (SRBs) on each side, and a large, cylindrical External Tank (ET) that carries fuel for the Orbiter's main engines. The Orbiters and SRBs are reused; the ET is not. NASA has three remaining spaceflight-worthy Orbiters: *Discovery*, *Atlantis*, and *Endeavour*.

The *Challenger* and *Columbia* Tragedies

More than 100 shuttle launches have taken place since April 1981. Two ended in tragedy, each killing seven astronauts. In 1986, the space shuttle *Challenger* exploded 73 seconds after launch because of the failure of a seal (an O-ring) between two segments of an SRB. In 2003, the space shuttle *Columbia* disintegrated as it returned to Earth after 16 days in orbit (see CRS Report RS21408, *NASA's Space Shuttle Program: The Columbia Tragedy, the Discovery Mission, and the Future of the Shuttle*, by Marcia S. Smith). A hole in *Columbia's* left wing, caused during launch by a piece of foam insulation that detached from the ET, allowed hot gases to enter the wing during reentry, deforming it and causing the shuttle to break up. The *Columbia* Accident Investigation Board (CAIB) found that the tragedy was caused by technical and organizational

failures, and made 29 recommendations, 15 of which it said should be completed before the shuttle returned to flight.[2]

Sean O'Keefe, NASA's Administrator from December 2001-February 2005, said NASA would comply with the CAIB recommendations.

Return to Flight (RTF)

NASA launched the space shuttle *Discovery* on the first of two "Return to Flight" (RTF) missions—STS-114—on July 26, 2005, and it successfully landed on August 9. On July 27, however, NASA announced that a piece of foam had detached from STS-114's ET during launch, similar to what happened to *Columbia*. Cameras and other sensors on *Discovery* and on the International Space Station—to which *Discovery* was docked for much of its mission—imaged the Orbiter and determined that it was not damaged, but further shuttle launches were suspended. Meanwhile, the images revealed that two "gapfillers"—ceramic coated fabric placed between thermal protection tiles—were protruding on the belly of the Orbiter that could have affected aerodynamic heating during reentry. One of the *Discovery* astronauts removed them during a space walk. The second RTF mission—STS-121—was scheduled for September 2005, but deferred.

STS-121 launched on July 4, 2006, and returned safely to Earth on July 17. The shuttle *Atlantis* launched September 9 on STS 115, during which construction of the International Space Station was resumed.

Current plans for the shuttle include nine more flights to complete the ISS before the shuttle is permanently grounded in 2010. Also planned is another flight to service the Hubble Space Telescope. Following the Columbia disaster, then-Administrator Sean O'Keefe had cancelled the Hubble servicing mission, partly on the grounds that shuttle astronauts would not be able to reach the ISS as a haven in case the shuttle was unable to return to earth. The decision was put under review by the new Administrator, Michael Griffin, and on October 31, 2006, he announced that the Hubble mission would be undertaken in 2008. The servicing would extend the life of the telescope through 2013. To deal with emergencies, NASA planned to prepare a "launch on need" mission with a second shuttle ready to launch on a rescue mission if the first was found defective during the servicing mission.

The launch was in final stages of preparation when a major data handling unit already in place in the Hubble telescope failed in late September 2008. A backup unit in the telescope was activated, but the service mission was revised to include carrying a second data handling unit, which had been stored on earth, to replace the failed one. NASA determined that assessing and preparing the second unit for installation and service would delay the mission until May or June of 2009.

The Shuttle's Future

NASA attempted unsuccessfully for many years to develop a "second generation" reusable launch vehicle (RLV) to replace the shuttle. In 2002 NASA indicated the shuttle would continue flying

[2] National Aeronautics and Space Administration. *Columbia Accident Investigation Board Report.* August 2003. See CRS Report RS21606, *NASA's Space Shuttle Columbia: Synopsis of the Report of the Columbia Accident Investigation Board*, by Marcia S. Smith.

until at least 2015, and perhaps 2020 or beyond. The *Columbia* tragedy, and President Bush's 2004 Vision for Space Exploration—to return astronauts to the Moon by 2020 and someday send them to Mars—forced NASA to revise that plan.

The President's Vision calls for the shuttle program, which absorbs approximately 25% of NASA's annual budget, to be terminated in 2010. A primary motivation is to make that funding available to implement other aspects of the Vision, although there also is concern about shuttle safety. Congress has been debating the Vision, including its impact on the shuttle and on U.S. human access to space. Some Members wanted to terminate the shuttle earlier than 2010 because they feel it is too risky and/or that the funds should be spent on accelerating the Vision. Others want to retain the shuttle at least until a new spacecraft, the Crew Exploration Vehicle (CEV), is available to take astronauts to and from the ISS. The CEV is now planned for 2015 at the earliest, leaving a multi-year gap during which U.S. astronauts would have to rely on Russia for access to the ISS.

The 2008 NASA Authorization Act (P.L. 110-422) included a provision requiring NASA to "terminate or suspend any activity of the Agency that, if continued between the date of enactment of this Act and April 30, 2009, would preclude the continued safe and effective flight of the Space Shuttle after fiscal year 2010 if the President inaugurated on January 20, 2009, were to make a determination to delay the Space Shuttle's scheduled retirement." (Sec. 611d.)

Shuttle Budget

Funding for the shuttle for FY2008 was $3.981 billion. For FY2009, NASA requested $2.982 billion for the shuttle, but that amount reflects NASA's new system for funding program overhead costs, which created a new Cross-Agency Support account. By the new accounting system, the comparable shuttle funding for FY2008 was $3.267 billion. The omnibus appropriations bill (P.L. 111-8) appropriated the requested $2.982 billion. (For details on the NASA budget, see CRS Report RS22818, *National Aeronautics and Space Administration: Overview, FY2009 Budget, and Issues for Congress*, by Daniel Morgan and Carl E. Behrens.)

Issues for Congress

In passing the 2005 NASA authorization act (P.L. 109-105), Congress basically agreed with the President's plan for directing NASA's attention to a return to the Moon and manned missions to Mars. Included in the Moon-Mars "Vision" is the plan to end flights of the Space Shuttle in 2010, and restriction of U.S. experiments on the ISS mostly to those that forward the goal Moon-Mars goal. A number of critical questions remain, however.

- Adequacy of funding is the chief question raised about NASA's activities. In presenting the Moon-Mars vision, the President did not request significantly increased money for NASA, despite chronic indications that the missions it was already charged with were underfunded. NASA has responded to the new mission by cutting back funding for its other activities, primarily in scientific research and aeronautics.
- Although *Discovery*'s "Return to Flight" mission of July 2006 was a success, the ability of the shuttle fleet to carry out enough flights to complete construction of the ISS by 2010 is still in question. With a history of more than a hundred

successful missions, it might be assumed that another 15 or so would be considered more or less routine, but instead, each launch is still a major and risky event. The great complexity of the vehicle and the extreme environment in which it operates require constant attention to possible accidents and malfunctions, many of which must be addressed on an ad hoc basis.

- The future role of the ISS is also unclear. Assuming that enough shuttle flights are made to carry out "core completion" of the station by 2010, it is not clear what will be done with the ISS after that. In particular, there will be a gap of several years between retirement of the shuttle in 2010 and beginning of flight of the Crew Exploration Vehicle, to be designed for the return to the moon but able to serve as a vehicle to reach the ISS.

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